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Reports
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SOUTHWESTERN CHAPARRAL, PINYON-JUNIPER WOODLAND, AND FOREST VEGETATION TYPE

18.1

(A Problem Analysis)

by

DONALD A. JAMESON

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Memorandum

Rocky Mt. Forest & Range Expt. Sta.
Forestry Sciences Laboratory,
Flagstaff, Arizona 86003

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TO : Director

DATE: August 14, 1967

FROM : Donald A. Jameson, Project Leader

SUBJECT: Range and Wildlife Habitat Programs (Problem Analysis)

The attached problem analysis was completed prior to the recent change in the specified procedure for submitting such analyses. Although this report is no longer required, it may prove to be of value as a working tool and will be kept on file in Flagstaff for reference.

Attachments-3

D. A. Jameson

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(A Problem Analysis)

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THE PROJECT AREA

The Southwestern chaparral, pinyon-juniper woodland, and forest vegetation types form a major portion of the western range comprising some 55 million acres (fig. 1). Although broadly grouped into three major vegetation types, the area encompasses climate conditions from semidesert to subalpine. The seasonal distribution of precipitation varies from Mediterranean to summer monsoon. Soils vary from incompletely decomposed sandstones to very heavy clays, and plant communities range from grassland to climax forest.

Grazing management ranges from sophisticated to crude. The emphasis in range improvement practices in the past has been on agronomic practices such as reseeding and brush control. Recently more attention is being paid to rotation and deferment systems.

Application of existing knowledge in the pine and pinyon-juniper types is beginning to provide a higher level of range productivity; such improvements can be expected to increase in the future. In these areas there is often an apparent conflict between range production and other uses, particularly between pine regeneration and range forage production. In the chaparral type, there is much less background information and the research approach will necessarily be different.

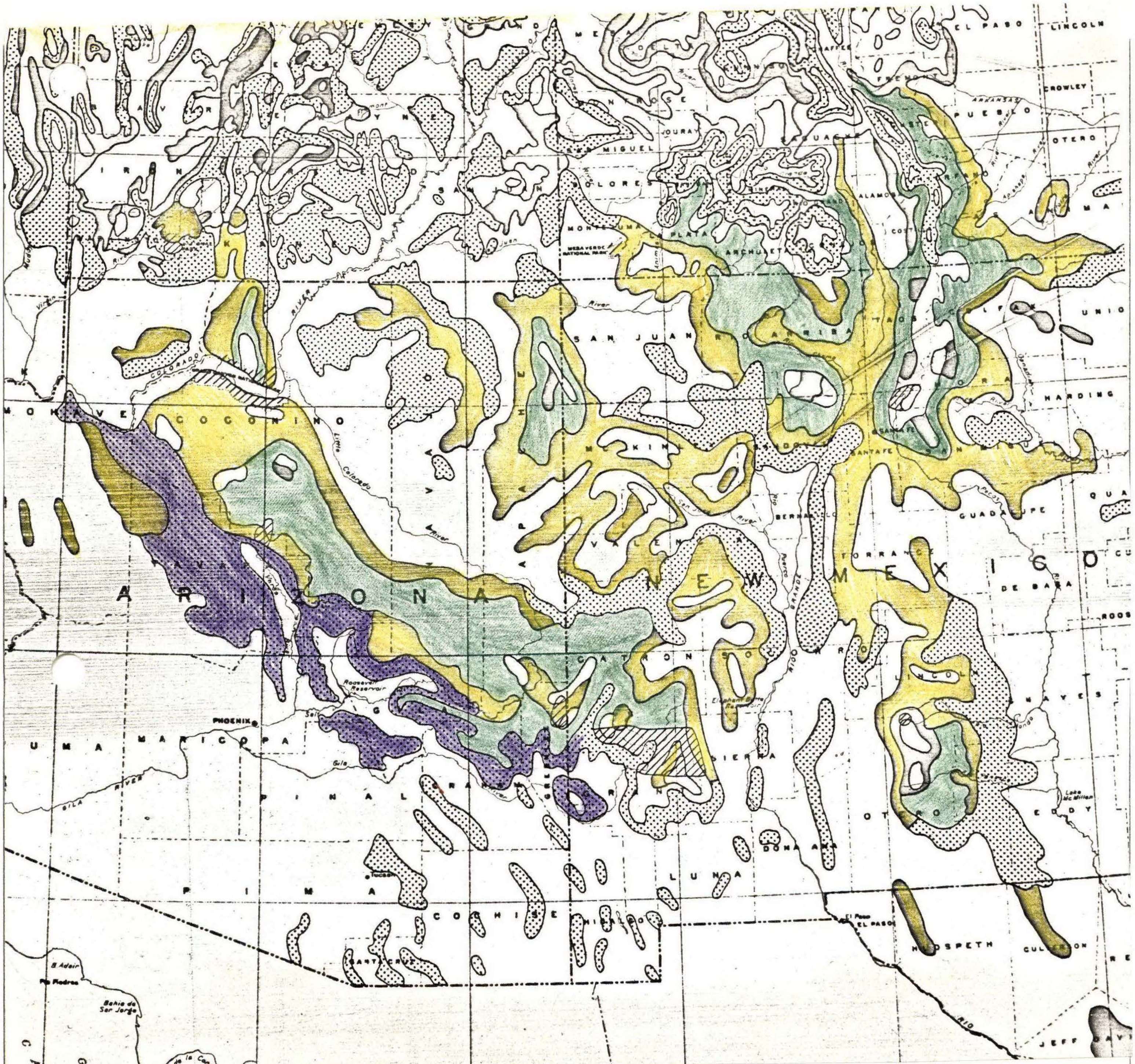

Figure 1. Vegetation map of the project areas.

Ponderosa pine

Pinyon-juniper

Chaparral

Thus, the problems to be considered are:

1. In the pine and pinyon-juniper types specific management and conflict of use problems which remain following management of ranges according to the best present techniques.

2. In the chaparral type the collection of ample background information to develop a more precise research program in the future.

APPROACH TO THIS ANALYSIS

The approach used in this analysis is one of a system analysis. This analysis considers that range management is a series of related systems whereby atmospheric gases, solar energy precipitation and parent material are processed to produce income to a ranch operator.

The Range System consists of four processing units:

1. The environmental integrator (soil).

2. The stationary biological processor (higher plants, lower plants, and lower animals).

3. The movable biological processor (higher animals).

4. The economic processor.

The basic system is outlined in Figure 2. Each unit has inputs from the preceeding unit and outputs to the succeeding unit. Each unit also has losses which may be utilized by other systems, but nevertheless are losses to the range system. Each unit has feedback to preceeding units. This system is further complicated by additional factors:

1. The processing units can be replaced. For example, reseeding is a fundamental change in the stationary biological processor. A change from cow-calf to steers is a fundamental change in the movable biological processor.

THE RANGE SYSTEM

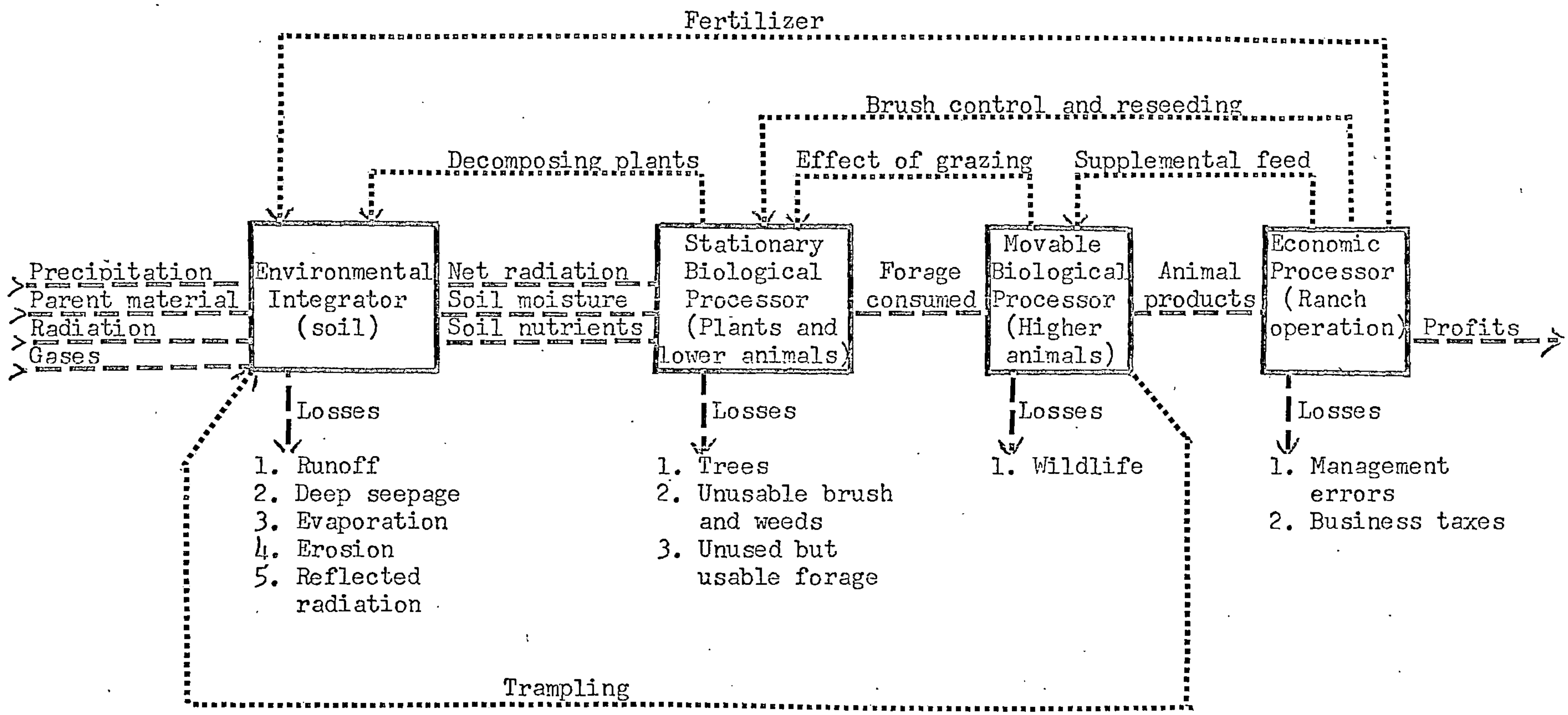

Figure 2.

2. The entire system operates through time, and outputs are generally nonlinear in time. For example, net radiation, available soil moisture, consumed forage, and animal products are all cyclic. The losses are also nonlinear in time.

3. Feedback loops are generally nonlinear, although some are quasi-linear. Overlapping feedback loops occur. In spite of these complications, following through such a system does point out some fruitful areas of research. We have an ad understanding of the general nature of most of the common processor units, but discrepancies in input/output ratios point out a few incongruities.

PRESENT KNOWLEDGE

I. Environmental Factors

A. Precipitation

The most prominent and unique feature of the Southwestern climate is the two distinct rainfall periods. Across Arizona and western New Mexico there is a gradual reduction of summer rainfall from east to west, and a decrease in winter rainfall from west to east. This pattern results in the maximum development of the two-season rainfall patterns in the Flagstaff-Prescott area (fig. 3).

The greatest winter rainfall in Arizona comes from storms moving eastward from lower California (fig. 4). As these storms move eastward they drop most of their moisture on the desert mountains of southwestern and central Arizona. These storms are particularly noticeable along the Mogollon Rim of central Arizona. The maximum moisture from these storms is near the Sierra Ancha Experimental Forest. Downwind from the Rim there is a distinct rainshadow, which is especially pronounced in the Little Colorado River basin. The importance of these California storms is almost entirely lost by the Arizona-New Mexico border. Thus, climatically speaking, the most prominant feature in Arizona is the Mogollon Rim, with a winter wet climate on the windward side and a winter dry climate on the lee side.

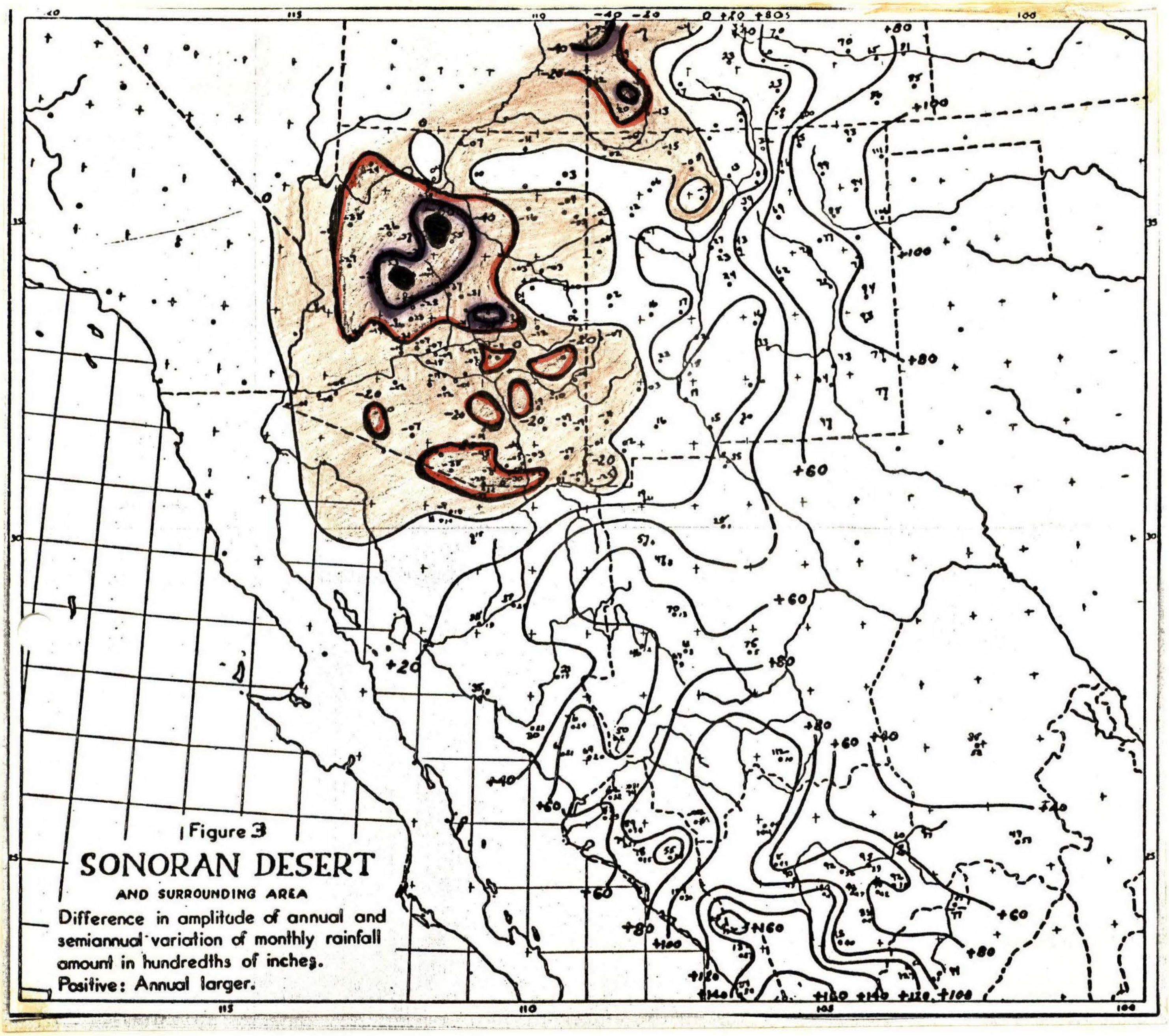

Figure 3.--Two-season effect in southwestern rainfall. Two-season effect is largest in darkest areas.

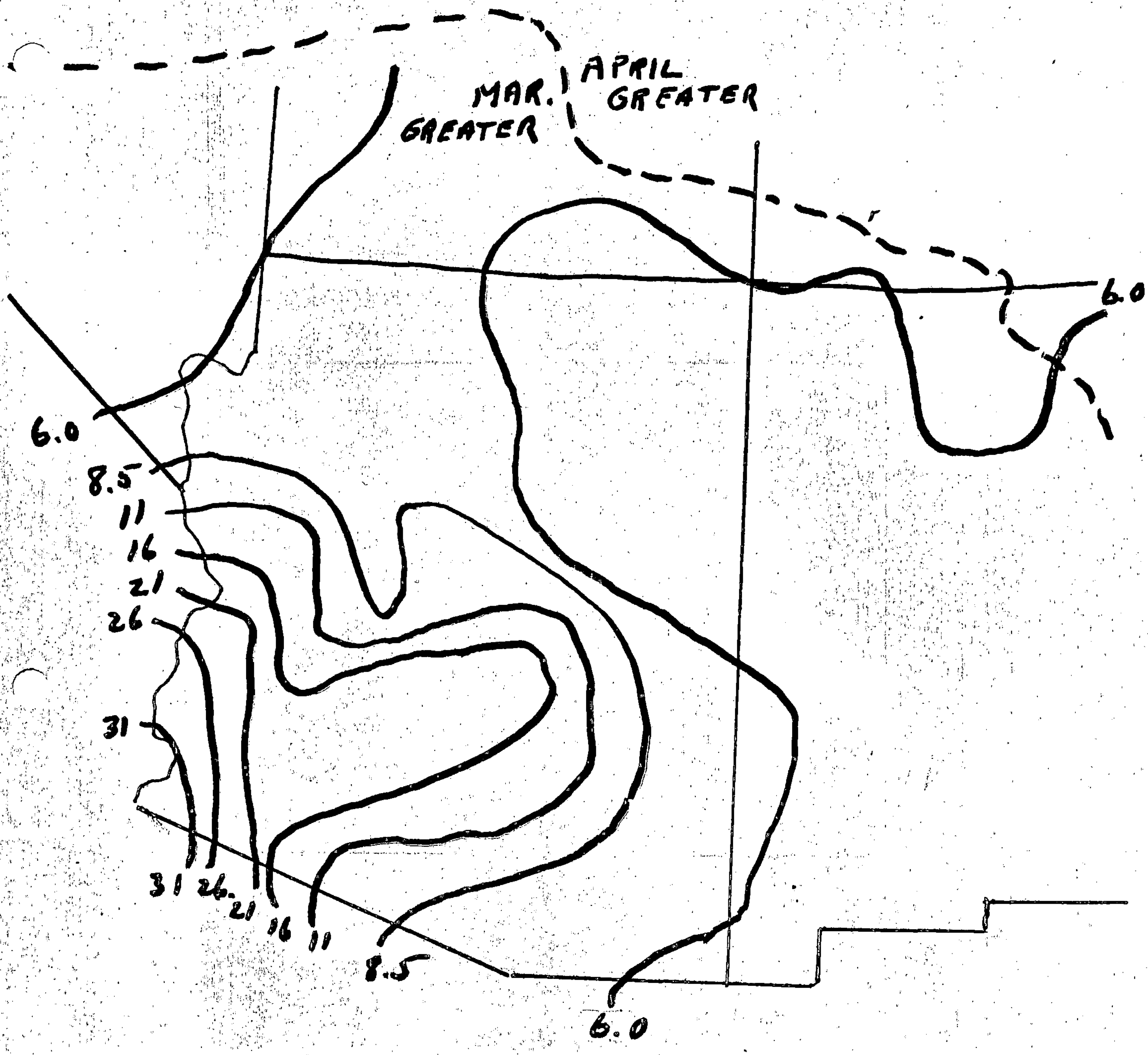

Figure 4. Distribution of winter storms in the Southwest. Isohyets show rainfall at the 5,000 foot level. Dashed line shows equal March-April precipitation--actual Great Basin climate extends to the south of dashed line.

Northern Arizona and New Mexico have a winter climate very similar to the winter climate of the Great Basin. This differs from the southern California pattern in that April is a higher rainfall month than March. Figure 4 shows the line of equal March-April precipitation. Below that line the winter moisture regime is predominantly Californian; above the line it is predominantly Great Basin in nature. Generally, the Great Basin storms lose their effectiveness before reaching the Little Colorado River.

Summer precipitation is predominantly from the Sonoran summer monsoon. In Arizona the peak activity of the summer monsoon is in the south central portion (fig. 5). The effect of the summer monsoon decreases rapidly toward the north.

Since the monsoon air masses do not show distinct frontal characteristics, there is no rain shadow effect as with the winter storms. Because much of the precipitation falls as a result of convection storms, high precipitation coincides with points of abrupt topography. The highest amounts of summer precipitation is at about the same location as the highest amounts of winter precipitation, i.e., in the Payson-Sierra Ancha area.

In east central New Mexico the Great Plains pattern of precipitation becomes evident. In the Great Plains May and June are peak precipitation months, in Arizona May and June

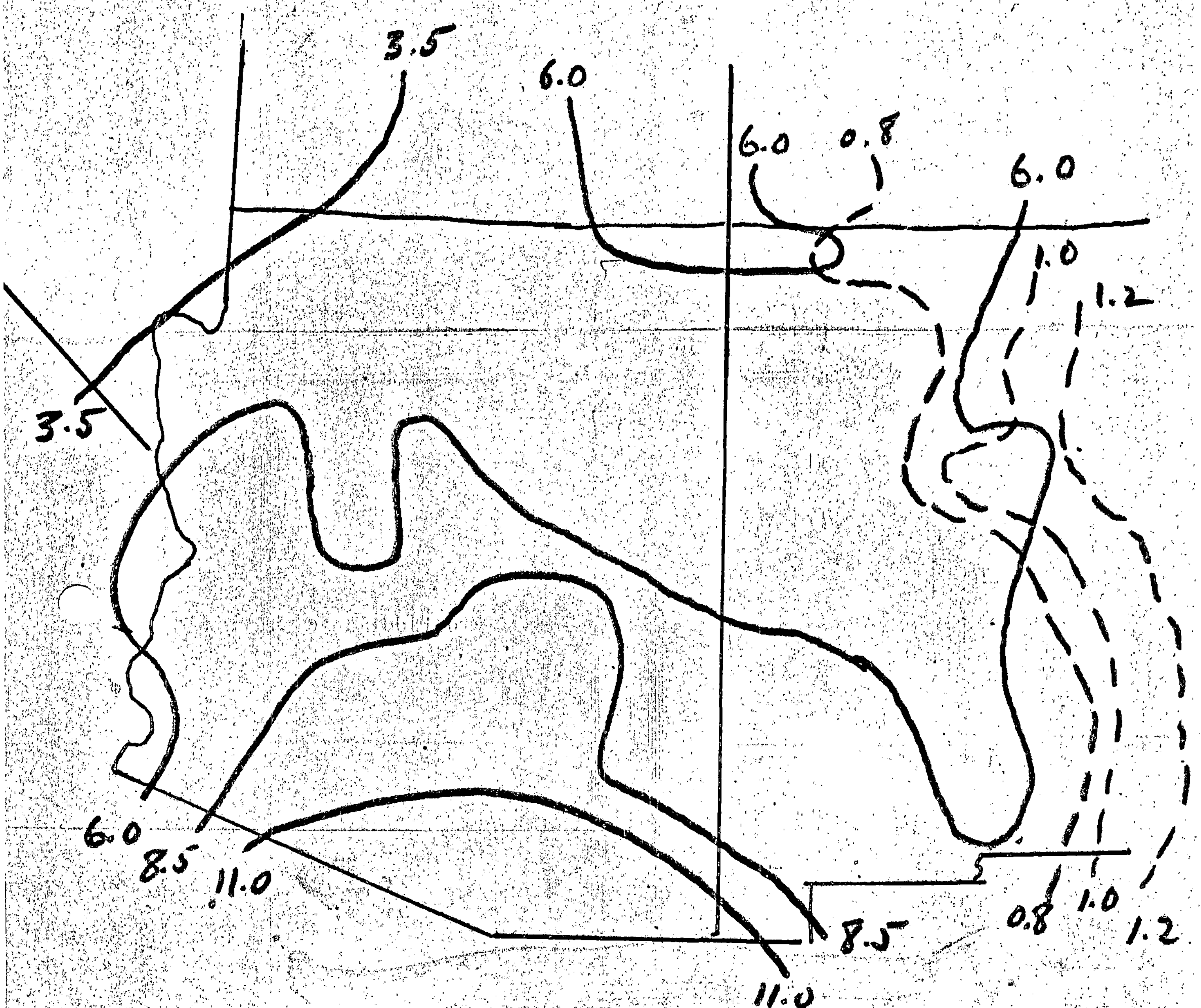

Figure 5. Distribution of rainfall from the summer monsoon. Solid lines are 5,000 foot isohyets. Dashed lines show ratio of May/June precipitation.

are drought months with peak precipitation being in August. Figure 5 shows the decline of May precipitation across eastern New Mexico. In west-central New Mexico the Great Plains pattern is almost completely lost. The dominant influences for western New Mexico and most of Arizona are these convection storms from the summer monsoon and winter frontal storms moving eastward from southern California.

Precipitation of various locations is shown in table 1 corresponding figures (6-10) show representative vegetation at these locations. Under each precipitation regime the vegetation grades to various species of juniper trees with increasing elevation and precipitation, but the associated species such as semidesert shrub, chaparral, sagebrush, or grasses remain as understories. All of the understories except southern desert shrub are also represented at even higher elevations where the juniper gives way to ponderosa pine.

These regimes are important in applying management practices. Techniques which are critically controlled by climate are often successful under one climatic regime, but not under another.

Climatic summaries for the southwest can be found in U.S. Weather Bureau annual summaries, in Smith (1956), Green and Sellers (1964), and Hastings (1964). Colton (1958) reported local precipitation near the San Francisco Peaks, and Thornthwaite (1942) discussed climate of the Polocca Wash. Recent rainfall distribution maps have been prepared by the U.S. Weather Bureau. Current research is being conducted by the Institute of Atmospheric

Figure 6. Sagebrush type with predominately winter precipitation (Fredonia-Jacobs Lake Road).

Figure 7. Chaparral vegetation near Prescott Airport, Arizona.

Figure 8. Semidesert vegetation near Winston, New Mexico.

Figure 9. Blue grama-juniper type near Snowflake, Arizona.

Figure 10. Blue grama type near St. Johns, Arizona.

Table 1. Precipitation and elevation at selected stations in Arizona and New Mexico

Elevation	Mount Trumbull, Ariz.	Prescott, Ariz.	Winston, New Mex.	Snowflake, Ariz.	St. Johns, Ariz.
	5,560	5,410	6,200	5,642	5,730
			Precipitation		
Annual	12.50	12.23	12.14	11.69	11.39
Jan.	.96	1.01	.55	.84	.69
Feb.	1.06	1.08	.60	.62	.70
Mar.	1.04	.73	.41	.60	.75
Apr.	.73	.69	.45	.63	.55
May	.53	.24	.52	.48	.52
June	.40	.32	.82	.49	.60
July	1.80	2.08	2.25	1.87	2.19
Aug.	2.04	2.66	2.75	2.50	2.11
Sept.	1.08	1.19	1.95	1.41	1.28
Oct.	1.03	.73	.97	1.02	.91
Nov.	.77	.50	.30	.58	.41
Dec.	1.06	1.00	.57	.65	.68
June - Sept.	5.32	6.25	7.77	6.27	6.18
Oct. - May	7.18	5.98	4.35	5.42	5.21
Fig. No.	6	7	8	9	10

Physics of Tucson, Arizona, and the U.S. Weather Bureau at Tucson, Arizona. A report by Bryson (1957) is representative of the former and a report by Kangieser and Green (1965) is a representative of the latter. This research has not as yet related climate to vegetation.

Vishen (1954) provides a good background of climatic patterns in the United States and Baker (1944) and Geiger (1965) discusses local modification due to topography.

The effect of weather on forage plant growth in the pinyon-juniper type has been studied briefly and reported by Jameson (1965). Nelson (1934) reported the loss of grass stands due to drought on the Jornada Experimental Range; Coupland (1958) and Albertson, Tomanek, and Riegel (1957) discussed the effects of drought on the Great Plains. These studies are most useful in pointing out that drought does have severe effects on range production. There have also been reports by Upson (1937) and Lister and Schumacher (1937).

Recently, tree ring studies (Glock 1961, Fritts 1965) have shown the relationship of present climate to long term climate. The study by Fritts is particularly inclusive. This study shows that a severe drought period occurred in Arizona and western New Mexico about 1905, followed by a wet period from 1910 to 1925. Hastings (1959) concluded that loss of forage due to overgrazing during drought periods, followed by wet periods, is the most likely reason for the great increase in woody plots which has occurred in the Southwest. Humphrey (1958) reached the conclusion that the main factor was fire, but the preponderance of the evidence seems to support Hastings' conclusion.

For the period 1931-1940, according to Fritts (1965) the Arizona and western New Mexico area had growing conditions almost identical to the 1501-1940 average. The very recent conditions have not been greatly different than the 1931-40 period. The present drought in the Southwest (Searles 1951, Barr 1956) is not unusual when the climate over hundreds of years is considered; rather "drought" in the Southwest is the usual state of affairs.

Vegetation distribution maps for the Southwest have been prepared by Nicol (1952), Castetter (1956), Whiting (1942) and U.S.D.A. Forest Service (1965). Merriam (1890) first pointed out the changes in plant communities with changes in elevation, and measurements of different weather conditions in the Southwest were first reported by Pearson (1931). One of the most recent studies of climate and vegetation is that of Johnsen (1962) who discussed the relationship of climate to one-seed juniper.

In summary, there is a considerable background of precipitation information for the Southwest and more is being developed by agencies primarily concerned with weather research. Long term weather records are scarce, but adequate interpolation can usually be obtained from existing stations when a picture of the long term climate is needed. Weather observations still need to be made in conjunction with certain types of vegetation studies. Studies of probabilities of rainfall will need to be conducted if probablistic approaches to analysis of rainfall-dependent range improvements are undertaken (Pattison 1965, Glover and LeBaron 1966).

B. Solar Radiation and Temperature

Solar radiation and temperatures are excessive in the lower regions of project area and at least adequate in all regions. There are two noticeable examples: *Muhlenbergia porteri* and *Poa fendleriana* are commonly found growing only in the shade of protective plants. Such phenomena should be documented, but it is doubtful if a feasible means of reducing solar radiation and soil temperatures can be found.

C. Gases

In rapidly growing crop land there is often a deficiency of carbon dioxide. Because of the low growth rates in the project area there apparently is no deficiency of carbon dioxide available to the plants.

II. Geology and Soils

Because of the arid climate, parent material has a very great influence on soils of the Southwest, and geologic maps are available for both Arizona and New Mexico. In addition, soil surveys by the National Forests and by the Soil Conservation Service are progressing rapidly and many survey reports should be published within the next few years. Some published information on soils and geology can be found in Martin and Fletcher (1943), Rich (1962), McKee (1936), Robinson (1913), Wilson (1962), Veatch (1920), and Carter and Cory (1932).

Approximate averages of parent materials within the Arizona pinyon-juniper type have been tabulated as follows:

Parent material	Thousands of acres
Volcanic	4,454
Kaibab formation	3,502
Jurassic sandstone	1,411
Mesa Verde formation	1,173
Coconino sandstone	1,156
Supai sandstone	612
Redwall limestone	578
Granite	408
Sand and gravel	510

In the ponderosa pine type about three-fourths of the area is basalt parent material, about one-fifth is Kaibab limestone, and the remainder is divided among the other parent materials listed for the juniper type.

In the chaparral the foremost parent materials are granite and granitic outwash, with schist and basalt next in importance. These four parent materials make up about 90 percent of the type, the chaparral in general is poorly developed on basalt and best developed on granite and schist. Other parent materials include diabase, Mescal limestone, quartzite, sandstone, etc., but none of these make up more than a small percentage of the type, except in the localized area near Roosevelt Lake.

Several basalt pine soils have been studied by Clary, Ffolliott, and Zander (1966). On these soils, highest productivity was in the swales and lowest was in the rocky ridges. The same general pattern holds in the juniper soils. In addition, skeletal limestone soils produce less than skeletal soils from other parent materials in the pinyon-juniper types. This may be related to lowered phosphorus availability in these soils (Sengupta and Cornfield 1963). The possibility of greatly improving production on these rocky soils seems extremely remote.

In the juniper type the Springerville soil constitutes a problem which possibly can be solved (fig. 11). This soil is a very heavy basaltic clay which is unstable (Vertisol). With a grass cover production is not much different than other ordinary upland soils. With the presence of juniper trees, however, the production on this soil is reduced much more than production of other soils. The reasons for this decline in production are at present uncertain, but there are several promising leads. Johnsen, Cady and James (1962) indicate that the clay of the Springerville series is predominantly montmorillonite complexed with organic matter. The bulk density is high and aeration is correspondingly low. Drainage is poor. Some counts of microbial population gave 700 colonies per cc in Springerville compared to 5,000 colonies per cc in other basalt soils. A low microorganism count is typical for

Figure 11. Springerville soil series in a Utah juniper stand.

montmorillonite clays (Stotzky, 1962). All of this information indicates that the growth inhibitors present in juniper (Jameson, 1961), which are normally oxidized by microorganisms or leached by water are accumulated in the soil. The enzymes responsible for oxidation of the inhibiting chemicals are copper containing proteins (Schubert, 1965). Preliminary analyses have shown that the copper content of Springerville soils is low.

Since the Springerville soils are heavy clays, they may have some physical effects on plants because of frost heaving (Anderson 1947, Biswell 1953, Schram 1958).

III. Losses from the Soil and Trampling Damage

Of the environmental factors which enter the soil complex, only soil moisture is limiting enough that we should concern ourselves with its loss. Hydrologists utilize the technique of soil moisture budgets to study such losses; extensive hydrologic studies are underway in the project area by Watershed Research and Forest Economics Research. Further work on soil moisture by Range Management Research will very likely be needed in the future.

Erosion of the soil itself is also a loss that needs to be considered. In most range management systems protection against erosion and maximizing the forage production are nearly synonomous. In the chaparral type, however, there may be a different problem. The bulk of the forage production is from shrubs which seem to provide little in the way of protection from erosion (fig. 12). Studies by Rich (1956) and Rich and

Figure 12. Soil erosion in the chaparral. Deep gullies have formed in bottom land alluvium.

Reynolds (1963) indicate that if grazing is light enough that no change in the grass cover is induced there is correspondingly no change in water yield and erosion. We have no knowledge of the erosion that could be expected if chaparral management were based on utilization of the shrub species, but we expect that losses would be mostly due to trampling rather than to reduction of cover.

IV. Decomposing Plants

In both the pine and pinyon-juniper type decomposed tree needles are a detriment to forage production (Jameson 1961, Clary and Ffolliott 1966). Although the effect is evident (fig. 13) the precise nature of the problem is still unclear. To date our attempts to identify the active components have not been successful.

V. Descriptions of Plants and Plant Communities

A. Communities

Studies on descriptions of plant communities have been confined mostly to the pinyon-juniper type as the following list of references indicate:

General.--Cottle 1931, 1932; Daubenmire 1943; Loftfield 1923-24; Lowe 1961; Rasmussen 1941; Reynolds 1962; Shantz and Zon 1924; Shreve 1942; Society of American Foresters 1957.

Pinyon-juniper.--Billings 1951, 1954; Bostick 1947; Bray 1940; Buchanon 1961; Deaver and Haskell 1955; Driscoll 1962; Eastwood 1919; Emerson 1932; Erdman 1962; Jameson, Williams, and Wilton 1962; Halls 1955; Livingston 1947; Merkle 1952;

Figure 13. Effect of pine litter on understory vegetation.

Mead 1930; Miller 1921; Olsen and Dykstehuis 1940; Palmer 1920; Parker 1945; Phillips and Mulford 1912; Plummer, Rixon, and Dodwell 1904; Potter 1957; Randles 1949; Read 1915; Reveal 1944; Stagner 1962; Turner 1913; Woodbury 1933, 1947; Woodhouse 1953; Woodin 1953; Woodin and Lindsey 1954.

Pine.--Arnold 1955; Dodge 1963.

Chaparral.--Hansen 1954; Illige 1954; Pase and Pond 1962; Pond and Cable 1962.

This list is by no means complete, but it does demonstrate the wide background of basic community description available in the pinyon-juniper type in contrast to the other vegetation type. Part of the reason is the extent of the pinyon-juniper type; there are some 60 million acres compared to 4 million acres each for the chaparral and southwestern ponderosa pine. Although the problems are less extensive in the latter two types, they are just as intensive. The Arizona chaparral, for example, is made up of many subtypes (fig. 12). The fact of the diversity is recognized, but published descriptions dealing with this diversity are almost completely lacking and there is no research underway. Our present study area at Tonto Springs is located on granitic outwash and is almost pure shrub live oak. A similar study on granite or schist parent material with a more diverse plant population needs to be established.

In spite of wide scope of information in the pinyon-juniper type, one can quickly question its value in a rigorous analysis of the problem. Descriptive ecology commonly only documents

the obvious. The real problems of the ecosystems are usually not touched in such documentation. For example, soil microorganisms, soil fertility, soil plant water relationships, etc., are usually not at all considered. Management practices cannot be intelligently planned based on a description of the ecosystem, but can be planned only bytbeing informed of the inputs available to and outputs demanded from it.

Nevertheless, without such background information there is little direction in a research program or management planning, even though the exact use of community ecology information is often not readily seen.

VI. Individual Species Components of the Plant-Lower Animal Community

We have, or soon will have, completed reports on phenology of most of our important plants. The pinyon-juniper phenology has been published, the phenology of the pine-type grasses has been submitted for publication, and phenology of the shrubs is being prepardd. We also have long term records of community changes in the pine and juniper type.

In any project area the number of autecological studies that could be undertaken on individual species are practically without limit. For example, we could study light, moisture, temperature and mineral requirements for germination and growth of any number of species. In any project area we could maintain that such information is scarce, as well it would be. The southwestern chaparral, woodland, and forest ranges are no exception. A few studies have been made, for example:

Olmstead 1952. Photoperiodism of gramas.

Benedict 1941. Growth of blue grama in reduced light.

Moore 1963. Germination inhibitors in achenes of Cerococarpus.

Lister and Schumacher 1957. Precipitation and grass growth.

There are a few other examples that could be cited, but not many more.

Since the study opportunities are essentially without limit, we must restrict ourselves in some way. First, which species are most important? Generally this means which are the most widespread, but areal extent may not be the only criteria. A species which is ordinarily produced in a fair amount and utilized in porportion by grazing animals does not demand the attention that a widespread weed species or a scarce, but highly utilized species does. Also, a limited, but preferred species loses much of its importance when a more widespread species is an adequate substitute. Secondly, what factors of importance to a species can be controlled? For example, most of our species could be vastly improved by additional water, but the possibilities of furnishing additional water are extremely remote.

Because of these factors, the choices of autecological studies are highly subjective. In our case we have chosen snakeweed (Gutierezzia spp.) (fig. 14) as the species demanding the most attention, and we have chosen it for bhe following reasons:

(1) It is extremely widespread. Gutierezzia is the second most important genus in the pinyon-juniper type, exceeded only by Juniperus, and it also extends into the pine and chaparral types.

(2) It is apparently not utilized at all by cattle under normal management even though it is utilized under very heavy grazing.

(3) It exhibits extremeevariations in abundance between years. This indicates that there may be some facet of its ecology which would provide a clue to its more effective management.

(4 (4) Although it is relatively easy to control with chemicals, we have no knowledge of how to stop or even reduce reinvasions.

Because of these reasons, intensive autecological research should begin with Gutierezzia. Background research includes Campbell and Bomberger (1943), a thesis from the University of Arizona, and unpublished research by Thomas N. Johnsen, Jr., ARS. In addition to its plant ecological importance, snakeweed is suspected of causing abortion.

VII. Plant Losses to the Range System

A plant loss to the range system is a species or parts of species which are not consumable, the retention of which is not required to sustain the desired plant community. Which species or parts of species are not consumed varies with the type of range management applied, but in general we can divide species into three general groups:

Figure 14. Gutierezzia is the most widespread genus in the project area.

(1) Those of which a major portion is consumed under most normal management systems. These are the "ice cream" and "key" species.

(2) Those which are not consumed at all or at least not under any but the most severe grazing pressure. In our project area this included crucifixion thorn, snakeweed, prickly pear, and large trees.

(3) Species which the degree of utilization can be regulated by type of management applied. Such species as shrub live oak and tobosa are in this category.

Ideally we should measure the production of both the consumable and nonconsumable species in order to determine the output of the plant community system. Practically, however, this is difficult to do and may be misleading even if it is done. For example, what comparisons can be drawn between the production of one pound of juniper and one pound of grass? What comparisons can be drawn between one pound of a species which grows mostly in the spring and a pound of a species which grows mostly in the summer? Because of these and similar difficulties, it is just as appropriate and much more feasible to measure the nonconsumable plants in terms which are easy to measure, and measure only the consumable plants in such output units as pounds. We find that relationships drawn between consumable plants expressed as weight and nonconsumable plants expressed in some other units are very

helpful. Examples are those of the chaparral (Pond 1964) the pinyon-juniper (Arnold, Jameson, and Reid 1964) and the pine (Pearson 1954). In each case there is a normal relationship between species or classes of species--a departure from the normal indicates an unusual condition. The Springerville soil in the juniper type is a case in point. In these soils the herbage reduction associated with a given juniper tree cover is much greater than for other soils (fig. 15); this indicates that a different set of factors are operating.

Usually we think that trees in semiarid situations represent losses to the range system because of competition for soil moisture with the consumable species. Sometimes, however, this is not the case. For example, there is apparently no competition for soil moisture between blue grama and juniper, rather the effect seems to be chemical or physical. Other examples of noncompetitive effects for both the project area and other areas are found in the following references: Arnold 1964; Börner 1960; Cacini 1963; Evanari 1957; Garb 1961; Glendening 1939; Grummer 1961; Jameson 1961; Muller 1953; Muller and Muller 1956; Rovira 1962; Sumere 1960; Woods 1960.

Examples of chemical effects of one species upon another are so numerous that one begins to wonder how any plant can survive with so many toxins collected in and on the soil. The answer is, of course, that normally such toxic products do not

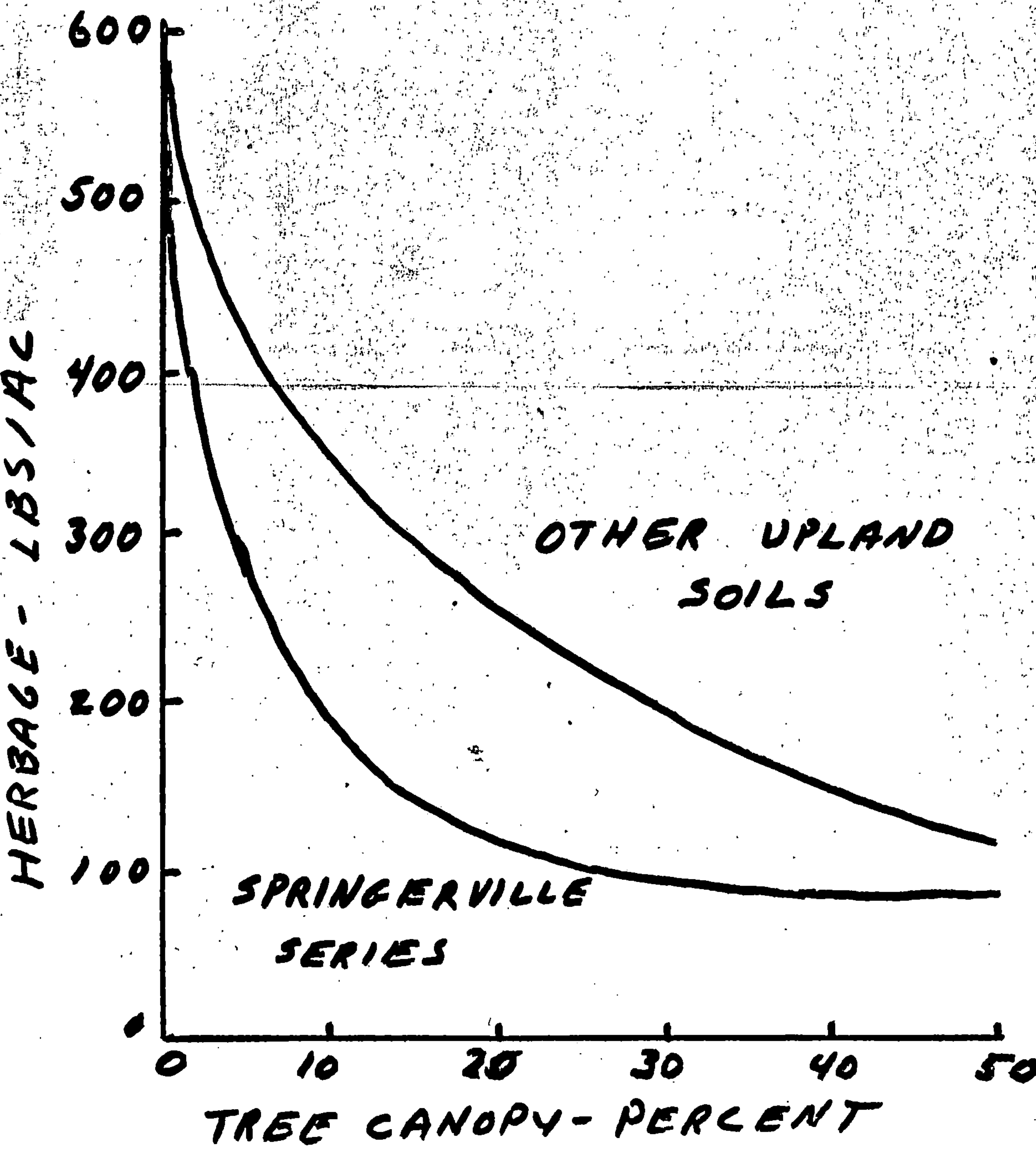

Figure 15. Overstory-understory relationships vary with different soils.

accumulate but are broken down by soil microorganisms. Good descriptions of the breakdown processes are found in Harborne (1964) (fig. 16) and Schubert (1965). If a serious problem of noncompetitive antagonism appears after a study of interspecific relationships, then a study of possible chemical affects is called for, including a study of soil microorganism and the various physical and chemical processes that influence the microbial activity.

IX. Effect of Grazing.

Effect of grazing on herbaceous plants has been reviewed by Ellison (1960) and Jameson (1963). In the case of shrubs there is a need for studies of the effect of grazing (fig. 17). Some work along this line is being done at Tonto Springs, but this work will need to be supplemented with additional work.

X. Higher Animals, Forage Consumption, and Supplemental Feed

Present work at Wild Bill and Tonto Springs is designed to show the relationship between consumption of digestible forage and animal weight gains.

At the Wild Bill study area in the ponderosa pine type the relationships are very close to the expected. At the Tonto Springs study area in the chaparral type, however, the animal output in the brush pastures in the winter is much too high for the grass forage inputs. The problem is that we had identified shrub live oak as a loss from the stationary processor when actually it is being used as an input to the moveable processor. During the winter, from 55 to 65 percent

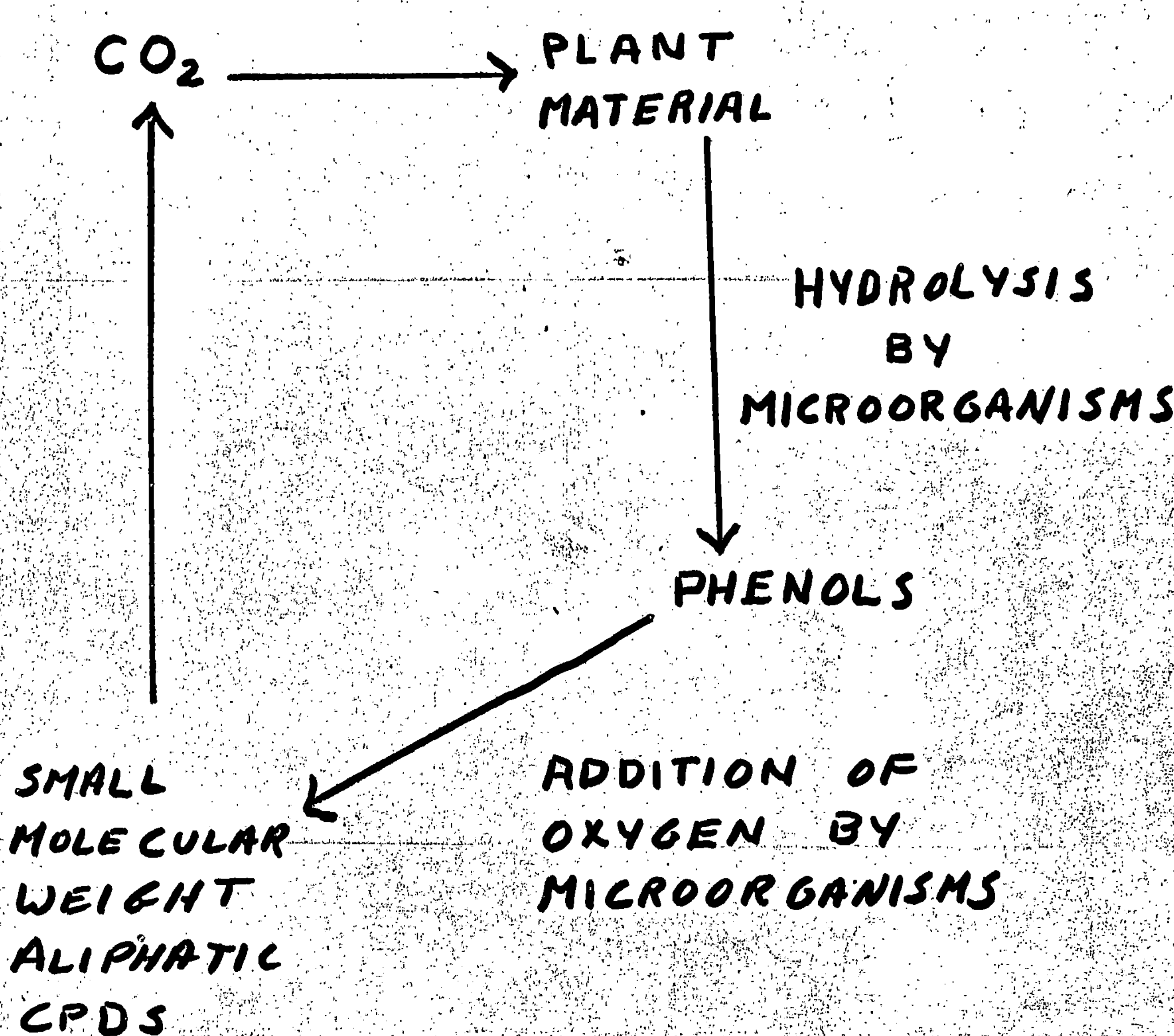

Figure 16. Normal process of litter breakdown.

Figure 17. Regrowth on grazed shrub live oak.

of the animal product output does not come from the grass under these conditions, and must be coming from the brush (table 2).

Two refinements are needed in these studies:

(1) The digestibility should be expressed as digestible energy; a high speed method of energy determination is needed for this analysis.

(2) Automatic weighing of animals is needed to reduce or eliminate weight losses due to handling.

So far all of our work has been done with yearling beef animals. We have no documented knowledge of cow-calf operations on these ranges. This deficiency of knowledge is most severe in wintering pregnant cows on chaparral ranges, least severe with cows and calves on pine and juniper summer ranges, and intermediate in wintering pregnant cows on juniper ranges.

The work at Tonto Springs has shown that shrub live oak is a major component of the cattle diet. We have no knowledge of the effect of very high percentages of shrub live oak intake on rumen ecology, cattle weight gains, and pregnancies. Calf crops in the chaparral are traditionally low; the cause is undetermined but it may be due to abortion inducing substances in the diet. Studies should be initiated to cover these aspects.

A beginning study on rumen ecology can begin with microorganism populations in *in vitro* cultures and microchemical and bioassay tests of possible toxins in the feed. Effects of feeds on abortion in ruminants likely will require more time, money, and effort.

Table 2. Grass and forb consumption (pounds per pasture) at Tonto Springs

Type of pastures	1964	1965
Native	6,800	9,400
Rootplowed	14,746	25,974
Native as % of plowed	46%	36%
Deficit in native forb consumption	54%	64%

No severe nutritional deficiencies are apparent in pine summer ranges or chaparral yearlong ranges. There are likely to be protein deficiencies on pinyon-juniper winter ranges and in such areas supplementing with a protein supplement is a common practice. If further studies show that high levels of shrub live oak in the diet are detrimental there may be opportunities for correcting the problem with selected supplemental feed. During the period of time covered by this analysis, however, such studies will not progress beyond the preliminary test tube stage because we do not know yet whether or not a problem exists.

We suspect that supplemental feeds may change the value, and perhaps the palatibility of some forages, especially browse, and we plan to investigate this. Economic feedback can be especially effective on the stationary processor where there is presently a loss that could be easily converted to an output. Chaparral species and tobosa grass are two examples. By applying proper management techniques much of such potential loss can be utilized. The chaparral is a particularly urgent problem since there is a vast area of essentially untapped forage.

XI. The Economic Processor

Ranch operations in the pinyon-juniper type have been described (Cotner 1963) and the summer-only ranch operations in the ponderosa pine type are relatively simple. Some work on ranch operations in these types has been done and is being done in connection with the Beaver Creek Project. In the chaparral, however, we need knowledge of how the ranch units operate and what their problems are. Such a study would undoubtedly point out other avenues for research.

XII. Brush Control and Reseeding

Brush control and grass reseeding in the problem area is handled by a team of Agricultural Research Service scientists located at Flagstaff. Good recommendations for reseeding in the chaparral and ponderosa pine types are available. Current ARS research is emphasizing the pinyon-juniper type and they are having considerable success with Luna pubescent wheatgrass and other species. In addition, Project 1704 is conducting research in browse plantings.

One possibility that is not presently being emphasized is planting of *Ceanothus greggii* (fig. 18). This species is a high producing, palatable browse plant which is not naturally present in abundance. Other chaparral browse plots are either abundant or unpalatable or both, but a greater amount of *Ceanothus* would be helpful.

In brush control there are many problems to be solved; in most cases other agencies and other uses are involved.

The ponderosa pine type represents the potentially highest producing area. Much of the ponderosa pine type is greatly overpopulated with pine trees, even from a forestry standpoint. At Wild Bill and Taylor Woods (Studies 14 and 15) the relationship between trees and herbage production is being studied. Some soils obviously do not have the same relationship between understory and overstory as the Taylor Woods-Wild Bill area (fig. 19). Manzanita (fig. 20), for example, is characterized by very low understory production. Since detailed studies of

Figure 18. Ceanothus greggii: a high producing and palatable but relative scarce browse species of the chaparral.

Figure 19. Some soils such as this decomposed granite support little understory vegetation.

Figure 20. Manzanita stands are characterized by lack of understory vegetation.

all soils would be impractical the first step should be a survey type study to determine which soils are problem soils in this regard. This and studies on litter breakdown discussed earlier should lead to future studies with direct management applications.

In the pinyon-juniper type the problem soils with regard to brush control have been identified. There are suitable mechanical brush control treatments available and also an accepted burning procedure for individual trees. A study on broadcast burning has been outlined (see section on program). ARS is working on chemical methods of control, but as yet these methods are rather expensive.

In the chaparral brush control studies are also underway by ARS. Further work in this area should await evaluation of ARS chemical control work, the Tonto Springs grazing study, and the prescribed burning program being conducted on the Tonto National Forest. At present it appears that areas with basalt soil in the chaparral can be managed for grazing without brush control; granitic outwash areas can be rootplowed.

XIII. Fertilizers

A very little work, except for one study by Lavin (1967) has been done on range fertilization in the problem area. Economic use of macro nutrients will undoubtedly be restricted to the higher rainfall areas; these rainfall restrictions should be identified. Use of micro nutrients, however, may be feasible over a much wider range of conditions. A

comprehensive study of micro nutrients should be undertaken. For maximum efficiency such a study should begin with greenhouse pot tests. This will of course require a greenhouse. At the completion of the pot test phase field plots should be established.

XIV. The Range System

Recent developments in mathematics and computers have led biologists to attempt simulation of ecological systems (e.g. Garfinkel 1962; Neel and Olson 1962; Odum 1960; Watt 1959). Results so far have been very encouraging, and there is real hope for progress in such a concept. It is perhaps noteworthy that biological systems analysis has been developed by medical doctors, and other biologists rather than by mathematicians. It has been pointed out earlier in this analysis that even our crude system concept has pointed out errors in our thoughts of the range system. A good starting point for such research would be in a better documented type such as the ponderosa pine; this should provide a framework for the chaparral type where less information is available.

PRESENT PROGRAM

Specifically, the present program includes the following:

Study No. 8

TECHNIQUES OF BROADCAST BURNING IN DENSE STANDS OF PINYON-JUNIPER TREES

Objective

Develop suitable methods of broadcast burning pinyon-juniper stands using chemical desiccants as an aid.

Status

Preliminary individual tree testing has been completed and the method shows promise. Large scale testing can be initiated as soon as an interested land management agency can be induced to treat a selected study area for an approximate cost of $2,000.

Leader.--Jameson

Comments.--This is a fire use study and could best be handled by fire research. A pilot study was initiated in 1967 on the Beaver Creek Watersheds.

Study No. 10

PRODUCTIVE POTENTIAL OF SITES IN THE PINYON-JUNIPER TYPE

Objectives

The overall objective of the study will be to determine productivity of various sites of the pinyon-juniper type expressed in grass production. This is to be accomplished in three parts; the first two parts have been completed.

1. A survey of the common boundaries of the tertiary volcanics and other geologic formations within the pinyon-juniper type to establish paired study plots at these boundary areas.

2. A comparison of the fertility and physical properties of soils developed from tertiary volcanics to determine the comparability of the volcanic soils at different locations.

3. To compare the productivity of selected pairs of plots selected on the basis of knowledge gained under objectives 1 and 2.

Status

All plots have been fenced and trees removed. Weeds were sprayed in 1965 and 1966, herbage samples were collected in 1964 and 1965. Herbage sampling will continue in 1967, 1969, 1971, and 1974. Weed spraying will be repeated when needed.

Leader.--Jameson. This study could be handled equally as well by Pond, but will not be transferred because of Pond's other workload.

Study No. 11

AUTECOLOGY AND PLANT COMPETITION IN THE PINYON-JUNIPER TYPE

Objectives

1. To gain information on the seasonal patterns of growth and development of some important forage plants of the pinyon-juniper type which can be used in developing management systems.

2. To determine the differences in establishment and production of grasses when released from competition of herbaceous weeds as compared to nonrelease.

3. To determine the presence and investigate the importance of germination inhibitors in weeds, trees, grasses, plant litter, and soils of the pinyon-juniper type.

4. To determine the nature of the effect of pinyon and juniper trees on grasses, and the effect of grasses on trees.

5. To determine the regularity and abundance of seed production and requirements for seed germination of important native forage plants of the type.

6. To determine the effects of unstable soils on plant establishment and growth.

7. To determine the climatic patterns of the type so that realistic management goals may be established within the various patterns.

Status

Objectives 1, 2, 4 have been completed and reports published. Work is continuing on objectives 3 and 6. Objective 7 has been covered by work of other agencies. No work has been done on objective 5.

Leader.--Jameson

Study No. 14

PONDEROSA PINE OVERSTORY EFFECT ON RANGE PRODUCTION

Objectives

The objectives of this research will be to study the overstory-understory relationships as follows:

PHASE I (Burro Mountain)

To determine the effect that different cutting practices and slash disposal methods have on the composition, cover and production of the herbaceous and shrubby vegetation of the mixed conifer type.

PHASE II (Taylor Woods)

1. To determine the effects of tree overstories on forage production.

2. To determine the effects of overstory treatment practices on forage production.

Status

Phase I is presently not yielding useful information and has been closed.

Phase II. Pretreatment measurements and measurements 2 and 4 years after treatment have been completed.

Study No. 15

EFFECT OF PONDEROSA PINE OVERSTORY ON FORAGE AND BEEF PRODUCTION

Objectives

The objective of this study will be to compare animal production on different degrees of conversion from pine overstory to grass:

1. To determine the effects of tree overstories on forage production.

   a. Quantity and composition of livestock and game forage

   b. Quality

      (1) Palatability and grazing and browsing patterns

      (2) Production of digestible nutrients

2. To determine the effects of various tree overstories on the value of forage and tree production.

Status

Vegetation and animal production data have been collected for 4 years on the untreated area and 2 years on the treated areas. The study should be continued 3 to 6 years under the present objectives.

Leader.--Pearson. This study and No. 104 both have aspects which are best suited for work by Pearson, but they also have aspects which are best suited for work by Pond.

Study No. 16

IDENTIFICATION AND ECOLOGICAL IMPORTANCE OF NATURALLY OCCURRING GROWTH INHIBITORS OF SOUTHWESTERN FOREST AND RANGE PLANTS

Objectives

1. To determine the presence of plant phenolic compounds which persist following normal decomposition processes.

2. To identify, if possible, the persistant chemicals.

3. To determine factors which can be manipulated that break down the persistant chemicals.

Status

Procedures have been developed which have allowed identification of the active inhibitors in juniper as isomes of chlorogenic acid. These acids are oxidized by the enzyme tyrosinase which may prove to be the clue to more rapid breakdown.

Leader.--Jameson

Study No. 104

COMPARISON OF CATTLE GAINS AND FORAGE PRODUCTION FROM CHAPARRAL IN NATURAL AND ROOTPLOWED AND SEEDED CONDITION

Objectives

The major objectives of this study are to: (1) Compare year-long animal production from grazing on (a) rootplowed and seeded chaparral and (b) on native chaparral and (2) compare animal production from grazing rootplowed and seeded pastures in summer and native chaparral in winter with animal production from pastures in native and seeded condition grazed year long.

Status

The third year of data, animal gain, and forage production is almost complete. Grazing pressure has been increased on all pastures and now approaches the desired level (40%) on rootplowed and seeded pastures. Proper use of native pastures, especially the browse, is difficult to obtain since little is known concerning proper browse utilization. However, cattle gains from both types have been comparable. Until some difference in animal gain, seasonal or otherwise, becomes apparent between types, additional animals must be added to chaparral pastures each year. So far, utilization of brush species, especially shrub live oak, has been negligible as measured by our techniques.

Leader.--Pond

Study No. 105

GROWTH, DEVELOPMENT AND NUTRITIVE VALUE

OF SOME CHAPARRAL SHRUBS

Objectives

The primary objective of this study is to gather information concerning the growth, development and nutritive value of several important shrubs of the chaparral type in Arizona. In so doing, the following specific questions will be answered:

1. When does growth begin and how long do the shrubs continue to grow during any one year?

2. What factors (rainfall, soil moisture, temperature) appear to regulate growth?

3. What is the crude protein, moisture and crude fiber content of current annual production at various stages of the plant's seasonal development?

Status

All data has been collected and summarized. A manuscript is in preparation and will close this study.

Leader.--Pond

Study No. 108

CHEMICAL AND BOTANICAL COMPOSITION OF THE DIET OF FISTULATED STEERS GRAZING IN THE ARIZONA CHAPARRAL

Objectives

The objectives of this chaparral grazing study are (1) to estimate the botanical composition of the diet of cattle, (2) to estimate digestibility of the cattle diet, (3) to compare the nutrient content of the cattle diet with the main forage producing species, and (4) to estimate forage intake of the cattle.

Status

Cattle diet and forage species samples were periodically collected from December 1965 through October 1966. These collections should be continued for 2 more years.

Leaders.--Pearson and Pond

STAFFING

The project is presently underfinanced for the existing staffing, and additional staffing must be accompanied by increased financing.

Addition of 2 scientists would bring the project up to the strength of the 10-year program, but 3 would be better in view of the diversity of the problems. Additional scientists would also necessitate additional support personnel (table 3). A proposed organization is as follows:

Project Leader

Provides project supervision and guidance. Conducts research in specialty field.

Animal Physiologist

Conducts digestibility studies on range browse and forage species, determines impact of "undesirable" diets such as shrub live oak on animal weights and reproduction. Most of this scientist's time and his basic research will be in the chaparral, although he will supervise digestion studies at Wild Bill and Beaver Creek which are by now mostly routine.

Range Scientist or Agronomist

Conducts agronomic type experiments where treatments are applied and vegetation response is measured in the field. Treatments are of field plot or pilot plant size. Treatments may include mechanical, chemical, or fire control of brush and addition of micro nutrients, or perhaps macro nutrients. Work will be about evenly divided among the pine, pinyon-juniper, and chaparral type.

Biosystems Analyst

Analyzes relationships between components of the range system. These components include environment, soil, plant and microorganism community, domestic animals, and ranch operations. Research techniques will resemble linear programming of economists and systems analysis of electronic specialists. This is an especially promising area of research, but recruiting a systems analyst with a good knowledge of biology will be a problem. Most need is in the chaparral type.

Microflora Ecologist

Studies impact of plant toxins which accumulate under conifers and in heavy clay soils. Develops methods of promoting breakdown of toxins. Most need is in the pinyon-juniper type, secondary need is in the ponderosa pine type.

Soil Scientist

Studies relationship of grazing practices to soil erosion. Particular need is in the chaparral type where management of the range for the most abundant species (shrub live oak) is suspected of creating an erosion hazard/ Management for the grass species, on the other hand, utilizes only about 5 percent of the potential of the type.

Experimental Area Superintendent

General supervision of larger experimental areas, including routine field data collection as specified by the scientists.

Technician (2)

Collection of field data.

Laboratory Technician (2)

Conduct routine laboratory analyses, particularly in artificial rumen digestion studies and soil microflora studies. An assistant will be needed during the summer months.

Data Processing Technician

Routine data processing, including key punch and automatic data processing equipment.

Greenhouseman

Provides routine maintenance of greenhouse and growth chamber studies.

(Page 60a follows)

Table 3. Staffing (man-years) and budget

Type of personnel	Existing	Needed for existing scientists	Needed with 3 additional scientists
Scientists	3	3	6
Experimental area superintendent	0	1	1
Field technicians, full time	3	1	3
Greenhouseman	0	0	1
Laboratory technicians	0	1	2
Summer field assistants	0		2 (6x4 mos)
Statistical clerk	0	1/2	1
Clerk stenographers	1/2	1/2	1
Approximate budget	$78,000	$130,000	$280,000

ADDITIONAL STUDIES PROPOSED WITH PRESENT STAFFING

1. Treatments for promoting sprouts of chaparral browse species. (Proposed for Pond)

2. Microorganism population with single and mixed in vitro diets of chaparral species. (Proposed for Pearson)

3. Ecology of snakeweed. Only preliminary investigation can be made without greenhouse facilities and with present staff. (Proposed for Jameson)

4. Establishment of Ceanothus greggii. In this study only preliminary investigations can be made without a greenhouse. (Proposed for Pond with some phases handled by Springfield)

Ecology + physiology [illegible]

5. Effect of shrubs on phenology and distribution of grasses. (Proposed for Pond)

ADDITIONAL STUDIES WHICH COULD BE UNDERTAKEN WITH ADEQUATE GREENHOUSE FACILITIES

1. Ecology of Gutierezzia (Expansion of proposed study)

2. Establishment of Ceanothus greggii. (Expansion of proposed study)

3. Micro nutrient deficiencies in soils.

ADDITIONAL STUDIES WHICH COULD BE UNDERTAKEN WITH ADDITIONAL STAFFING

1. Relationship between grazing and erosion in the chaparral. This study could be done by the watershed research group and should at least be done in cooperation with that group.

2. Basic rumen ecology in the chaparral type.

3. Survey of soil microorganism populations. Alternatively, this could be handled under cooperative agreement.

4. Fertilization trials in the pine and chaparral types. Community ecology on alluvian, basalt, and residual igneous and metamorphic sites of the Arizona chaparral.

5. Range Systems Analysis. Nowhere in the range management field is there a study of systems analysis such as there is in insect population dynamics and predator-prey relationships. A system analysis investigation back up by a staff of biologists should yield good results.

COOPERATIVE STUDIES

Cooperative studies needed in conjunction with either the abbreviated or expanded program include:

(1) An economic analysis of ranch operation in the Arizona chaparral.

(2) A survey of soil microorganism populations on selected range soils.

PROJECT PUBLICATIONS

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OTHER LITERATURE

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